THE NEURAL CORRELATES OF INSTINCTS AND HABITS

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Introductory.—In a previous study[1] the writer essayed showing what kinds of group activities untrained subjects generally beat, and how they could be classified. In the present paper the writer wishes to present the same kinds of facts in relation to certain new kinds of facts and, further, to show how such facts may be employed analytically for the determination of the properties of the nervous system, and to what preliminary conclusions such analytical operations lead.

A. Experimental

1. Definitions.—A distinction will be made between periodic activities and rhymical activities. By the former will be understood any series of regularly made activities amongst which either no differentiation occurs, as by accentuation or otherwise, or where such accentuation occurs vicariously. By the latter will be understood any series of regularly recurring activities amongst which a regularly recurring differentiation occurs, as by accentuation or otherwise, and irrespective whether such movements have conscious rhythmical accompaniments or not. Except where specifically stated to the contrary, the present paper is limited to a consideration of periodic activities in the sense of the above definition.

By a 'group' we shall understand any periodic activity which is a continuous function of a finite time interval or

[1] Bock, C. W., A Classification of Groups, *Psychobiology*, Vol. 1919.

duration, and such an activity can be most conveniently obtained from human subjects by requiring them to beat, i. e. tap, say, on the button of a tambour, *for any desired duration in any desired rate or tempo.* A 'group' has therefore the following properties: a number (G) which describes any particular activity or group with respect to the number of its contained beats or elements; a number (D) which describes a group with reference to the time interval or duration required for its consummation; a number (T) which describes a group with respect to the rate at which its elements, beats, are given; and a number, or an expression (K), which describes a group with respect to its structure or complexity. In the experimental portion of this study we shall be concerned with these variables, their manner of variation, and the correlations that obtain for such variations.

Our observers were instructed to *"beat as long as you desire in any desired rate, and then rest as long as you desire; so continue beating and resting until you are finally instructed to cease."* Thus made the activities in question were not conditioned by the specific environments of the subject but were solely conditioned by or within him. For their explanation we may hereafter therefore not appeal to environmental factors, save only the instructions, which however can strictly be said to condition only the series of groups and rests as such, but not a specific group or rest. In order to safeguard these conditions as much as possible, and maintain their status quo, certain precautions were taken or not taken depending on one's point of view. First, our observers were not permitted to count while beating. Second, lest the beating become a possibility of experience to the subject we required no introspections or self-observations. Third, lest such self-observations occur notwithstanding we encouraged, by non-prohibition chiefly, the performance of any other compatible activity simultaneously with beating, such as reading, studying, talking, singing, whistling, humming, smoking, 'thinking,' etc., with the result that both activities went on simultaneously and apparently dissociatively. We justify this procedure for the reason that we could not have prevented such extraneous activities had we so desired, except possibly under hypnosis, and also because we were not at all concerned with the specific condition of any given group or rest, so that if these extraneous activities did condition the specific nature of a group and rest, well and good. The extraneous activities are of course of the same nature as group activities and every argu-

ment as to their condition is equally applicable to both kinds. Finally, no reference was made to the word 'rhythm' or its connotation for reasons that will be stated hereafter. It should be said however that our subjects generally showed no tendency to beating rhythmically, except under certain conditions of which mention will be made.

The data on which the present study is based were derived from an aggregate of 11 subjects who beat a total of some 300 records, each consisting of from 20 to 50 groups and rests each. The material selected for presentation herein can therefore only be illustrative of the mass of records actually analyzed, but it should be understood that the facts which this selected material portrays are generally typical for all observers and all records. Tracings were made of all records in the usual manner. Time was counted in seconds, fifths, and 100ths, as specifically stated for each case, and approximated to halves, tenths, and two-hundredths.

2. Group Variables.—It is convenient to indicate by example the kinds of facts to which attention will be generally called herein. Subject S beat the following groups among an array numbering twenty-three:

G.	D.	T.
128	50.5″	.394″
258	75.0″	.282″
256	63.0″	.249″

It is to be observed that the 128 group on the one hand and the 256 and 258 groups on the other are multiples; that the 256 and 258 are obviously variants of some common type group, the 256 undoubtedly; and that the following equations may be set up for them:

$$G\text{—}128 = G\text{—}128$$
$$G\text{—}258 = G\text{—}128 + G\text{—}128$$
$$G\text{—}258 = G\text{—}256$$
$$G\text{—}256 = G\text{—}128 + G\text{—}128$$

It is also to be observed that the corresponding durations (D) and therefore the tempi (T) (which are calculated from the formula $T = D/G$) vary, but *not* in the sense of the groups to which they correspond; and further, that the said durations and tempi are likewise multiples of a common number, 12.5 seconds; set down comparatively, the relations that obtain among the above groups, their durations, and their tempi are as follows:

G—128: G—256=1:2;	D—128: D—256=4:5;	T—128: T—256=8:5.
G—128: G—258=1:2;	D—128: D—258=2:3;	T—128: T—258=4:3.
G—256: G—258=1:1;	D—256: D—258=6:5;	T—256: T—258=5:6.

This illustration serves for the formulation of the thesis of this study,—that group coefficients, (G), durations, and tempi are functional variables; that the primary form of such variability takes the form of ratios of small integers; and that the variability of each is not necessarily in the sense of the others.

A record, 11-9-18Ca, of Observer C is given in Table 1.

Ob. C. 11-9-18a TABLE 1

G.	D.	R.	T.	T/Ta.	T/Tt.	E.	R.
38	7.5	21.5	.197	147.5	150.0	2.5	2/3
63	18.5	29.0	.290	158.5	160.0	1.5	8/5
108	20.0	35.0	.183	152.0	150.0	2.0	2/3
216	60.0	113.5	.278	200.0	200.0	0.0	1/2
54	30.0	45.5	.556	304.0	300.0	4.0	1/3
140	25.0	35.5	.183	119.0	120.0	1.0	5/6
117	25.5	25.5	.218	115.0	114.0	1.0	7/8
53	10.0	37.5	.190	162.0	160.0	2.0	8/5
209	64.5	20.0	.308	195.0	200.0	5.0	1/2
85	13.5	....	.159				

We have herein an example exactly parallel to the preceding in the following complex of groups:

G.	D.	T.
108	20.0″	.183″
216	60.0″	.278″
54	30.0″	.576″
53	10.0″	.190″

Set down comparatively, the following relations exist among the group variables:

G— 53: G— 54=1:1;	D— 53: D— 54=1:3;	T— 53: T— 54=1:3.
G—108: G— 54=2:1;	D—108: D— 54=2:3;	T—108: T— 54=1:3.
G—216: G—108=2:1;	D—216: D—108=3:1;	T—216: T—108=3:2.
G—108: G— 53=2:1;	D—108: D— 53=2:1;	T—108: T— 53=1:1.
G—216: G— 53=4:1;	D—216: D— 53=6:1;	T—216: T— 53=3:2.
G—216: T— 54=4:1;	D—216: D— 54=2:1;	T—216: T— 54=1:2.

We observe from the above that multiple groups occur; that the durations of such multiple groups are different and themselves multiple, but not in the sense of the multiplicity of the corresponding groups; that the same group (or variant) occurs in different durations; and finally, that the tempi of the groups are to each other as the ratios of small integers, octaves and fifths predominating.

Cursory examination of the record (Table 1) will show that the coefficients (G) of certain groups are apparently sum-

mations of other coefficients of the same record. In particular, the following instances thereof occur:

G—54 + G—85 = G—140 (140–1)
G—63 + G—54 = G—117
G—38 + G—38 + G—140 = G—216
G—38 + G—63 + G—108 = G—209
G—53 + G—85 = G—140 (140–2)
G—63 + G—53 = G—117 (117–1)
G—38 + G—63 + 2G—54 = G—209
G—38 + G—63 + 2G—53 = G—209 (209–2)
G—38 + G—85 + G—85 = G—209 (209–1)

Table 2 gives the temporal correlates of the above group summations, and is conceived on the basis of the following considerations. It was to be expected on a priori grounds that the duration of the summation group would be equal to the sum of the durations of the alleged components, but this is only rarely the case.

TABLE 2

G	D	R	An.	d	D	R
38	7.5	21.5	....	....	....	...
63	18.5	29.0	....	....	....	...
108	20.0	35.0	2–54	10.0	30.0	1/3
			2–53	10.0	10.0	1/1
216	60.0	113.5	2–108	30.0	20.0	3/2
			4–54	15.0	30.0	1/2
			4–53	15.0	10.0	3/2
			140	40.0	25.0	8/5
			2–38	10.0	7.5	4/3
54	30.0	45.5	....	....	....	...
140	25.0	35.5	54	15.0	30.0	1/2
			85	10.0	13.5	3/4
			53	15.0	10.0	3/2
			85	10.0	13.5	3/4
117	25.5	25.5	63	14.0	18.5	3/4
			54	11.5	30.0	3/8
			63	14.0	18.5	3/4
			53	11.5	10.0	8/7
53	10.0	37.5	....	....	....	...
209	64.5	20.5	38	11.5	7.5	3/2
			63	19.5	18.5	?
			108	33.0	20.0	5/3
			38	11.5	7.5	3/2
			63	19.5	18.5	?
			2–54	16.5	30.0	5/9
			38	11.5	7.5	3/2
			63	19.5	18.5	?
			2–53	16.5	10.0	5/3
			38	11.5	7.5	3/2
			2–85	26.5	13.5	2/1

Accordingly it became our problem to determine what relationship existed between the duration of an alleged component as it occurred in the summation group and its duration as it occurred as such within the record. We therefore pro-rated the duration of the summation group among its components, and got derived durations which we compared with the durations which generally occurred in the record, and particularly with the durations of the components themselves. The plan of the table (Table 2) is in accord with the above; 'An' indicates the analyses of the corresponding groups of column 'G,' 'd' is the derived or pro-rated duration, 'D' the original duration, and 'R' the ratio of the derived to the original duration. It will be observed, first, that more frequently than not a given group has more than one set of alleged components, and second, that the derived duration is generally related as the ratios of small integers to the original duration. Sometimes also the same derived duration attaches to different groups.

Reference to Table 1 will show another class of facts. Considered successively and in pairs the tempi of groups are to each other or tend to be to each other as the ratios of small integers. In this table 'T/Ta' is the actual quotient of successive tempi; 'T/Tt' is the nearest simple theoretical ratio; 'E' is a measure of the error involved and is the difference between the actual and theoretical ratios, while 'R' is the fractional form thereof. A last class of facts is also indicated in Table 1. It will be observed that the same durations are recurrent, that multiple durations occur, that frequently the same duration attaches to a rest period as to groups, and that durations occur that are obviously summations of other durations.

Table 3 gives a record of the same observer and was made under slightly different conditions. Instead of resting on the completion of a group the observer was instructed to "*beat another group, or several such, in different tempi.*" He accordingly beat 'sets' of groups between which he rested (rests are not indicated in the table), but otherwise under the same conditions as previously. Time was measured in fifths of a second and approximated to tenths, etc., on a relatively fast moving drum. The plan of the table (Table 3) is as before and shows the same kinds of facts. Table 4 summarizes the principal ones. Particular mention should be made of the fact that whenever the 31 group occurs at the beginning of a 'set of groups' it numbers 31 beats; when it occurs in the

middle or at the end of such, it numbers one beat less, i. e., 30 beats. The reason therefor is obvious. In counting out these groups we included in the first one all beats up to the time when the tempo of beating changed, and so on throughout the whole set of groups. We questioned our observers on the propriety of this procedure, asking whether it appeared to them as if the beat before the tempo change occurred belonged to the preceding or to the succeeding group. We ourselves tried to determine the question phenomenologically, and

Ob.C. 7–3–18b. TABLE 3

G.	D.	T.	T./Ta.	T./Tt.	E.	R.
46	8.67	.189	234	233	1.0	3:7
14	6.20	.443	233	233	0.0	3:7
28	5.33	.190				
31	8.67	.280	220	225	5.0	4:9
14	8.67	.618	275	275	0.0	4:11
30	6.75	.225	247	250	3.0	2:5
22	12.00	.555				
47	13.50	.287	206	200	6.0	1:2
22	13.00	.590	250	250	0.0	2:5
28	6.60	.236	250	250	0.0	2:5
22	13.00	.590				
45	7.88	.175	268	267	1.0	3:8
28	13.20	.470	251	250	1.0	2:5
44	8.25	.187	251	250	1.0	2:5
14	6.60	.471				
31	6.80	.219	260	267	7.0	3:8
14	8.0	.571	245	250	5.0	2:5
30	7.0	.233	253	250	3.0	2:5
14	8.25	.590				
31	8.25	.366	166	167	1.0	3:5
30	18.25	.609	214	214	0.0	7:15
14	18.25	1.300	800	800	0.0	1:8
45	7.34	.168				
31	7.40	.233	251	250	1.0	2:5
14	8.20	.585				
31	7.17	.231	262	266	4.0	3:8
14	8.15	.606	340	333	7.0	3:10
28	5.0	.178	254	250	4.0	2:5
14	6.33	.451				

TABLE 3—Continued

50	8.50	.168	276	275	1.0	4:11
14	4.65	.465	188	187	1.0	8:15
30	7.40	.247	259	265	6.0	3:8
14	9.00	.641				
49	8.40	.171	240	233	7.0	3:7
30	12.33	.411	197	200	3.0	1:2
30	6.33	.210				
47	11.17	.238	243	250	7.0	2:5
30	17.33	.578	346	350	4.0	2:7
30	5.00	.176				
31	7.60	.245	256	250	6.0	2:5
14	8.80	.630				

TABLE 4

G.[1]	G.[2]	D.[1]	D.[2]	T./Ta.	R
46	31	8.67	8.67	666	2/3
14	46	8.67	8.67	333	1:3
14	31	8.67	8.67	500	1:2
22	22	13.00	13.00	1000	1:1
14	31	8.25	8.25	500	1:2
14	44	8.25	8.25	333	1:3
31	44	8.25	8.25	667	2:3
14	14	8.20	8.25	1000	1:1
30	14	18.25	18.25	500	1:2
28	22	6.60	13.00	666	2:3
14	30	6.33	6.33	500	1:2
31	30	7.40	7.40	1000	1:1
28	14	6.60	6.60	500	1:2
28	30	5.00	5.00	1000	1:1
30	47	6.75	13.50	666	3:2

agreed with our observers that this last beat really belonged to both the preceding and to the succeeding groups. In other words, the final beat of the first group was also the first beat of the second group, etc. This assumption is borne out by the facts;[2] the intermediate groups which number 30 beats are factually groups of 31 beats precisely as the first 31 groups; the 14 group which occurs as an intermediate is factually a 15 group, i. e., the half of the variant multiple group 31. Particular attention should also be called to the predominance

[2] It also accounts for the final accent of isolated groups generally.

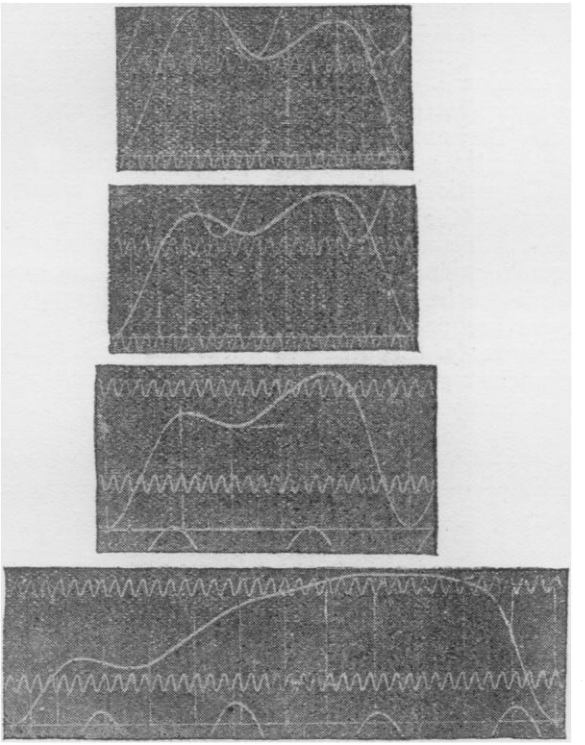
of the ratio 2:5 and possibly also the ratio 3:8. The observer casually remarked during the beating "that he had fallen into a rut, i. e., it appeared to him as if he were beating not only the same groups, but these in apparently the same general tempi." As a matter of fact he was beating quite a variety of tempi, but he was beating the same tempi successions predominantly. It should finally be noted that the duration 8.67 seconds occurs within a span of 5 groups three times, once for each of the groups 46, 31, and 15, i. e., for multiple or multiple variant groups. Other facts of the same kind are indicated in table 4.

The principal facts of a record of Observer S are indicated in table 5. The record is itself not included, but it as all records generally manifest the same tendencies heretofore shown. Of particular interest is the recurrence six times of the duration 46.5″ for three different groups and for two rest periods. The unusual predominance of the octave, fifth, and fourth relationship among the tempi of the indicated groups is also to be noted. When the 46.5″ duration occurs for different groups, these are related as the ratios of small integers; similarly for other identical durations. Multiple, identical, variant groups also occur. Summations occur but are not specifically indicated.

TABLE 5

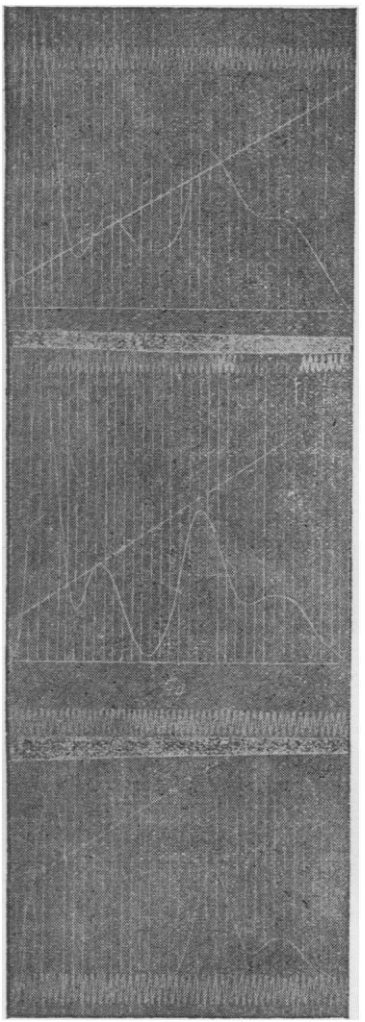
$G._1$	$G._2$	$D._1$	$D._2$	$G._1/G._2$	$D._1/D._2$	$T._1/T._2$
64	192	37.5	37.0	1:3	1:1	3:1
107	214	18.5	37.0	1:2	1:2	1:1
110	165	33.0	33.0	2:3	1:1	3:2
180	181	40.5	40.5	1:1	1:1	1:1
149	112	46.5	46.5	4:3	1:1	3:4
217	164	46.5	46.5	4:3	1:1	3:4
217	149	46.5	46.5	3:2	1:1	2:3
180	181	40.5	67.0	1:1	3:5	5:3
134	132	43.0	64.0	1:1	2:3	3:2
111	111	22.0	42.5	1:1	1:2	2:1
288	143	52.0	68.0	2:1	3:4	8:3
112	112	21.0	46.5	1:1	4:9	9:4
110	111	33.0	22.0	1:1	3:2	2:3
164	165	33.0	46.5	1:1	5:7	7:5
90	180	45.0	40.5	1:2	9:8	4:9
90	181	45.0	67.0	1:2	2:3	4:3
112	217	46.5	46.5	1:2	1:1	2:1
78	110	66.0	33.0	5:7	2:1	5:14
149	417	46.5	46.5	2:3	1:1	3:2

3. Analysis.— We were led to the conclusion by inference from the facts of the preceding section as well as by the problems which considerations of 'amplitude' set, that a beat was a complex event which might be resolved into its constituent elements. We therefore so arranged our manner of taking records that our curves would lend themselves to



FIGS. 1-4

analysis, and applied the Fourier analysis to them in quite the same manner as these analyses are made of sound-wave tracings. It is important to remember that the application of the method to the analysis of curves of any kind in fact postulates the analysis it attempts. There is therefore no guarantee that actualities of function correspond to analysis, except for the confirmation that such analyses bring to other classes of facts from which the same inferences or conclusions obtain. It is



FIGS. 5-7

primarily for this reason that we find it convenient to anticipate the results of a study in preparation for the past year on the analyses of rhythm forms.

Our analyses are based on two methods chiefly. The first, that of Tait, quoted and employed by Fleming, Jenkin, and

Ewing [3] in their well known study of the analysis of phonograph tracings, lends itself readily for wave forms that are simple and short of duration, and permits the calculation of the first six partials. The second, that of Maartens [4], is applicable for more complex wave forms such as rhythms and for activities of longer periods, permitting the calculation of the first 18 partials. Erecting the number of ordinates to the curve as required by the particular mode of analysis employed, we measured the same in centimeters and fifths of a millimeter. This was accomplished through the mediation of a very finely etched steel rule and a high power reading glass to the back of which was stretched a rather fine black horse hair. In measuring, the glass was held so that the hair coincided with the intersection of the ordinate and the curve (really the glass was stationary, the curve being moved into the required position), and the reading on the rule was taken. The curves themselves were got by the method of Bingham slightly modified [5], i. e., the method of direct registration without the mediation of a tambour.

Herein no attempt will be made to deal with the question of phase differences. The results of the analyses will be simply indicated together with the tracing of the curve. For the simple beats the 'a' coefficients represent the sine terms and the 'b' coefficients the cosine terms. For the several rhythm forms the converse is true.

FIG. 1

a_1	a_2	a_3	a_4	a_5	a_6
—0.55	—0.62	—0.09	+0.05	.....	..
+0.05	—0.09	—0.03	+0.04	+0.02	..
b_1	b_2	b_3	b_4	b_5	b_6

FIG. 2

a_1	a_2	a_3	a_4	a_5	a_6
—0.58	—0.52	—0.11	+0.16	—0.03	..
—0.29	—0.04	—0.05	.....	—0.07	..
b_1	b_2	b_3	b_4	b_5	b_6

FIG. 3

a_1	a_2	a_3	a_4	a_5	a_6
—0.61	—0.29	—0.14	+0.18	+0.03	..
—0.30	.....	.....	+0.03	—0.04	..
b_1	b_2	b_3	b_4	b_5	b_6

FIG. 4

a_1	a_2	a_3	a_4	a_5	a_6
—0.43	—0.21	—0.21	+0.01	.....	..
—0.51	.....	—0.01	—0.24	.....	..
b_1	b_2	b_3	b_4	b_5	b_6

[3] Trans. Royal Society Edin., vol. 28, p. 750.
[4] *Archiv fuer Math. u. Physik,* Reihe 3, Bd. 17, 1910.
[5] Psychological Review Monograph Suppl., No. 50, 1910.

FIG. 5

a^1	a^2	a^3	a^4	a^5	a^6	a^7	a^8	a^9	a^{10}
+0.09	+0.72	+0.36	+0.48	+0.05	—0.07	—0.10	—0.02	—0.06	—0.03
+0.04	+0.37	+0.13	—0.43	—0.36	—0.30	—0.10	—0.10	—0.07	—0.05
b^1	b^2	b^3	b^4	b^5	b^6	b^7	b^8	b^9	b^{10}

FIG. 6

a^1	a^2	a^3	a^4	a^5	a^6	a^7	a^8	a^9	a^{10}
+0.19	+0.80	+0.15	+0.62	+0.05	—0.06	—0.18	—0.13	—0.13	—0.09
+0.11	+0.05	—0.24	—0.23	—0.46	—0.35	—0.14	—0.08	—0.03	—0.02
b^{10}	b^2	b^3	b^4	b^5	b^6	b^7	b^8	b^9	b^{10}

FIG. 7

a^1	a^2	a^3	a^4	a^5	a^6	a^7	a^8	a^9	a^{10}
+0.22	+0.61	+0.02	+0.22	—0.18	—0.20	—0.04	—0.04	—0.01	.....
+0.11	—0.29	—0.28	—0.45	—0.14	—0.05	—0.04	—0.02	—0.03	—0.02
b^1	b^2	b^3	b^4	b^5	b^6	b^7	b^8	b^9	b^{10}

FIG. 8

a^1	a^2	a^3	a^4	a^5	a^6	a^7	a^8	a^9	a^{10}
—0.03	+0.07	—0.05	—0.02	.....	—0.10	—0.03	.....	—0.02	—0.02
+0.15	+0.12	+0.34	—1.05	+0.06	+0.50	+0.16	+0.04	—0.03	.....
b^1	b^2	b^3	b^4	b^5	b^6	b^7	b^8	b^9	b^{10}

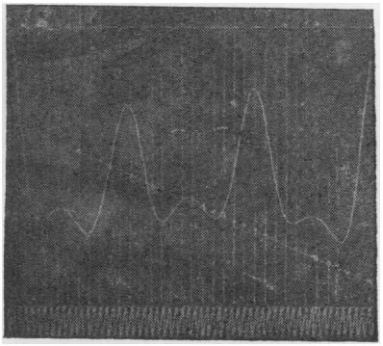


FIG. 8

The conclusion to be derived from the analyses of the above curves is obvious if actualities of function correspond to actualities of analyses. Beats are complex events, or may be conceived as such, and have components, primary components, whose coefficients (G) are to each other as the ratios of small integers, the durations or periods of the latter being also related as the ratios of small integers. With the more detailed facts of these analyses we shall not be presently concerned, and we may therefore postpone their discussion to a later paper of this series.[6]

[6] Attention should be called in passing to certain significant ratios which obtain among the amplitudes of the several components; cf. analyses, Figs. 3, 4, 5, 6, 7, 8. For example, in Fig. 3, $a_1 = 61$, $b_1 = 30$, i.e. 2:1; $a_1 = 61$, $a_2 = 29$, i.e. 2:1; $a_1 = 61$, $a_2 = 29$, $a_3 = 14 = 4:2:1$, etc.

B. Theoretical

4. Introduction.—The point of departure of the present discussion is an expression,

$$G = D/T$$

which is on the one hand a descriptive generalization of group activities, and which expresses on the other hand the formal relationships which exist among their principal properties, number of contained beats (G), duration (D) and rate or tempo (T). The expression is nevertheless an abstraction, for it contains no factor for the group property 'structure' or 'complexity' (K), and no factor for the group and beat property 'amplitude.' We shall however find it convenient to consider the expression and its implications in the above more simple form, reserving a more complete formulation of the group equation for a later time in the discussion. Nothing which shall hereafter be said depends upon such present omission.

The expression $G = D/T$ is perfectly general, and may be regarded either explicitly or implicitly. Explicitly, it makes the group property 'G,' number of contained beats, the dependent variable, whose nature and numerical value in any particular case are conditioned by or are incidental to the natures and values of the properties 'D' and 'T,' the independent variables. Implicitly, any of the above three factors may be regarded as the dependent variable, and accordingly any two as the independent variables. The question arises which is the dependent and which are the independent variables.

This question assumes the validity of the conclusions arrived at in the experimental portion of this study, particularly those which declare the independent variability of the factors 'D' and 'T' with respect to 'G' and reciprocally; and from its form we may therefore state our first general deduction from the facts herein presented, namely, *that a full and adequate description of group activities involves at least two independent variables whose natures and values condition the nature and value of a third dependent variable;* from which it follows as a corollary, *that the neural structures involved for the production of group activities must be correspondingly complex and independently variable.* And this is the justification of the question previously put; for by the selection of our independent variables we define at the same time the properties

and variability of the neural complexes involved for the beating of groups.

The expression $G = D/T$ declares a physiological possibility that any given group is conditioned by two factors, one having duration and the other having rate. Since both 'D' and 'T' are independently variable, no other real alternative exists. The expression $D = GT$ declares a physiological possibility that the factor duration is derived and conditioned by two factors, one having rate, the other 'counting.' No other real alternative exists. Finally, the expression $T = D/T$ declares a physiological possibility that the rate of beating is derived and conditioned by two factors, one having duration, the other 'counting.' No other real alternative exists. In each of the above three cases an apparent alternative exists. For instance, we might in each case imagine the two independent properties attaching to a single, simple neural mechanism, there being as many such as there are possibilities of beating in different tempi and durations, each mechanism having both properties simultaneously. Our argument is not invalidated by this possibility, for we should yet have the same properties to deal with and to account for. Our problem in either case consists in choosing between a duration mechanism and a counting mechanism, either one in conjunction with a rate mechanism, or in conjunction with each other and to the exclusion of a rate mechanism.

Our appeal must be to physiology, particularly to neural physiology, where however we find no duration mechanism, no counting mechanism, and no real rate mechanism. Accordingly we shall be required to examine such concepts as we may find in the physiological stockroom, making application thereof for the explanation of group activities, and determining their limitations for explanatory purposes. The basic concept of neural anatomy and physiology is the meaning which currently attaches to the expression 'neurone theory,' which we shall regard as understood. The basic functional concept is the meaning which currently attaches to the expression 'reflex arc theory,' which meaning we shall assume as understood. Finally, the basic concepts for the explanation of activities other than simple reflexes are the meanings which attach to such expressions as 'concatenation of reflexes,' 'neurone chains,' etc., etc. Of subsidiary concepts there are the meanings which obtain for such expressions as 'resistance,' 'reciprocal innervation,' 'drainage,' 'deflection,' 'permeability,' 'synapse,' 'facilitation,' 'inhibition,' 'summation,' 'conduction rate,'

' fatigue,' etc., etc., all of which we shall assume as understood. Our present problem is the explanation of a certain group of assignable properties by the above concepts.

The group activity to be explained neurally is one of 22 beats (i. e., G = 22), duration 11.0 seconds (i. e., D = 11.0), tempo 0.500 seconds (i. e., T = 0.500), of simple structure (E = 1-22). The last named expression, that involving structure, we shall explain hereafter; it is sufficient presently to indicate that it has been assumed in such a manner (possible theoretically) that it will not enter into the discussion as a factor. We continue, apparently at least, to abstract from ' amplitude.' Assuming the first beat as environmentally conditioned, we have explained the first beat (antagonistic reflex). The second beat may not be environmentally explained, and neither may any of the other beats. There are two other possibilities for the explanation of the second and remaining beats of the group in question. They may be peripherally conditioned or centrally. On the basis of the first assumption we could imagine the downstroke of the second beat conditioned in the same manner as was the upstroke of the first beat conditioned, i. e., antagonistically (antagonistic reflex, concatenation, reciprocal innervation, etc., etc.), but the question would immediately arise; how is the variable rate of beat succession thereby explained, or in the case at issue, what conditions the period 0.500 seconds? The differential mechanism for a variable rate of beat succession might be imagined as having its locus in certain muscular sense organs; but even so, how is their differential functioning conditioned? also peripherally? The assumption of a central condition for a variable rate of beat succession has the same disadvantages. If centrally conditioned, the central condition may not be explained as itself environmentally conditioned, but assuming that the central condition were satisfactorily explained otherwise, what conditions the differential rate at which these central reflexes follow each other? Some mysterious synaptical transformation? But even if it were possible to explain the second and succeeding beats by such concepts as ' reciprocal innervation,' ' concatenation of reflexes,' ' after-discharge,' etc., there would still be the difficulty of understanding why the beating, once initiated, should not go on till exhaustion. Why does the beating stop so mysteriously at the conclusion of the 22nd beat? Of course, if certain group activities did not recur more frequently than would be indicated by a chance distribution, this mysterious stopping could receive the obvious explanation.

But the 22 group recurs time and time again, not only in one duration but in many different durations, and the idea of 'vicarious functioning' is inadequate. The traditional explanation applied in similar cases is the meaning which attaches to the expression 'reflex inhibition,' but a reflex inhibition requires an explanation as well as a reflex excitation. As a matter of fact we shall hereafter show that the rate of beating as well as the duration of beating are conditioned with and even before the first beat of a group is conditioned.

The logical fallacies which underlie present day neural and behavioral concepts are obvious. Activities are at least two-dimensional; the reflex arc doctrine is a uni-dimensional manifold whose elements are reflexes. With this unidimensional concept we can explain only unidimensional activities, simple reflexes, and not all of them. Two-dimensional activities require two-dimensional concepts, i. e., concepts which contain the proper and necessary differential possibilities. The subsidiary ideas of the reflex arc doctrine do not add such possibilities. In consequence thereof writers on behavioral subjects have generally contented themselves with making purely formal applications of the theory, or, where less formal attempts were made, have made up their theoretical deficiencies by borrowing the necessary variables from the environment by appealing thereto,—variables which ought to be in the explanatory mechanisms. We contend that the reflex theory is adequate for the explanation of simple reflexes properly so-called, but we can see no hope of its ever being adequate for the more complex forms of behavior,—for such forms as instincts, habits, 'willing' etc., etc., precisely for the reason that it is too simple and contradicts a formal requirement, that it contain as many variables as there are such in the activities to be explained. It is our present problem to attempt introducing the necessary variables into the reflex arc concept, and accordingly we recur to our previous statement, that this problem resolves itself into a choice between a counting mechanism and a duration mechanism, either in conjunction with a rate mechanism, or in conjunction with each other and to the exclusion of a rate mechanism. Of these possibilities we shall choose or postulate the existence of rate mechanisms and duration mechanisms for reasons as follow:

(1) The choice of a rate mechanism and a duration mechanism is the simplest possible assumption that can be made, for both duration and rate mechanisms are of the same

order, the former involving generally short durations, the latter long periods.

(2) A counting mechanism, i. e., mechanism which is simple and unitary, and which, once initiated, performs a certain number of times and then ceases, exists nowhere in nature or among artificial contrivances; on the other hand all artificial contrivances are combinations of rate and duration mechanisms.

(3) Rate mechanisms exist everywhere in nature, really exclusively to all others; further such mechanisms have already been postulated for the heart-beat and for respiration.

(4) A duration mechanism would be an additional requirement for activities that were not periodic of form. Counting mechanisms would therefore be superfluous.

(5) The postulation of duration mechanisms satisfies certain genetic requirements of which mention will hereafter be made.

(6) The facts of analysis point to rate mechanisms.

(7) Together and properly conceived, the postulation of duration and rate mechanisms suffices for a complete explanation of the facts herein presented, and for the facts of behavior generally.

Without bothering for the present to discuss the theoretical reasons which underlie the assumptions here made, or the consequences of these assumptions on current physiological ways of thinking, we shall make application thereof in a preliminary manner for the explanation of the same group activity for which the reflex arc theory was inadequate, namely, the group 22, of 11.0 seconds duration, and 0.500 seconds rate, still abstracting from the structure and amplitude factors. We assume first a neurone whose functional rate of discharge is 0.500 seconds; second, another neurone whose functional rate of discharge, i. e., whose duration of discharge is 11.0 seconds; third, a spatial orientation of these two neurones of such a nature that when the latter shall have been conditioned (and provisionally we shall assume an environmental condition) it shall discharge into the former, thereby conditioning 22 cyclic periodic discharges thereof. The analogy we would offer is that of the simple mechanism of a watch or clock. Herein the mainspring represents the duration mechanism, the hairspring the rate mechanism, the gears the spatial nexus; depending upon the mainspring, the duration of ticking will be a day, a week, a month, or a year; depending upon the hairspring, the watch will tick seconds, halves, fifths, hundredths,

thousands, etc. The ticks made by the clock will therefore be a function of the particular hairspring and mainspring it possesses, and since both kinds of springs may vary in their respective ways, a watch or clock may be made which shall beat any desired number of times at any desired rate. Such variability we shall therefore assume for the neural analogies hereto.

Since the facts presented indicate that an organism can and does beat in a large number of different tempi, we must assume as many different neural mechanisms, i. e., rate mechanisms, as there are rates of beating simply; since the facts presented indicate that an organism can and does beat in many different durations, we must postulate as many duration mechanisms generally as it beats different durations; and finally, since the facts presented indicate that durations and tempi are generally independently variable, it follows that we must assume the spatial nexus as between these two classes of neurons correspondently complex. And hereby we shall have conceived our mechanisms for the more simple and elementary facts of group activities.

5. Group Structure.—There are certain classes of facts whose explanation is not quite so simple as the foregoing, which indicates that our conceived mechanisms are too simple. We have purposely conceived the simpler case first and may now proceed to a discussion of group structure and its implications.

The facts are these: a given group, say the 22, occurs regularly in different durations and different tempi; but more frequently than not, when this happens, both durations and tempi are related as the ratios of small integers. This phenomenon is of regular occurrence in activities other than groups. The same melody is generally perceived as such, i. e., it is the same melody, irrespective of the rate in which it is played or sung. The same melody learned on the piano, say, is generally speaking learned not only in the rate at which it was practised but also in any other desired rates. Now the important implication of this class of facts is this, that whatever was or is a condition for the 22 group in any given tempo was or is a condition for that group in any other tempo, but more particularly in *related* tempi and durations. To the consideration of this class of facts must be added that of another, namely; records show that the beating of a given group in a given duration and tempo is associated with the beating of its multiples in the same durations and tempi, or in other durations and tempi,

but most particularly in related durations and tempi. Now it would be quite simple to explain a group and its multiple whose durations were in the sense of their own multiplicity; it would be simple, for instance, to explain the 22 group of 11.0 seconds duration and the 44 group of 22 seconds duration. All that would be required is the assumption that the 22 group mechanism functioned twice in strict succession, and this is precisely what happens under certain conditions. At the same time it should be understood that this explanation, however simple and obvious, would not explain how it came about that the 22 group mechanism functioned twice in succession, i. e., this assumption would not be a complete explanation. The problem under consideration does not involve this simple case; it involves the case where the beating of a certain group in a given duration and rate is associated with beating the multiple of that group in the same duration or in related durations and rates; and the same implications as previously obtain, namely, that whatever was or is a condition for beating the 22 group in a given duration and rate was and is a condition for beating the multiple, 44, in the same or in related durations and rates. Finally, a third class of facts require consideration. Our records show that more frequently than not a given group may be summated from among the coefficients of other groups occurring in the same record, and frequently such summations are not limited to a single set of alleged components but often there are many such componential possibilities. Analysis of such cases shows further that frequently when the durations of a summation group are pro-rated among its alleged components, and when such prorated durations are compared with the original durations of the components, prorated durations often correspond to durations that occur therein for other groups, or for the alleged components themselves, or are related to these as the ratios of small integers. The case is simple where the sum of the durations of the components groups is equal to the duration of the summation group, and the explanation is obvious with the reservations as previously made for a similar case. In the case where the sum of the durations of the component groups is not equal to that of the summation group the inference lies close at hand that, while the components with the durations and tempi as in the record occurring may not be components of the summation group, they may be such in the tempi and prorated durations of the summation group. This inference is substantiated by the fact that the prorated durations are to the original durations as the ratios

of small integers. At any rate the same implications obtain as previously, namely, that whatever was or is a condition for the beating of different groups in different durations and tempi, is or was a condition for beating their sums in related durations and tempi.

Our whole discussion obviously hinges upon the meaning that is to be assigned to the expression 'whatever was or is, etc. . . . was or is a condition, etc.,' and to the facts of 'relatedness' as applied to durations, tempi, and group coefficients. This meaning becomes clear when we remember the possible inferences that attach to the facts shown by the mathematical analyses of beats and rhythm forms. If a beat were a simple event, motorly or neurally, obviously the subject would be performing a relatively simple activity in beating a 22 group, say, and possibly explicable on the assumptions heretofore made. But the beat is not a simple event. It is or may be conceived as a complex event, consisting of the algebraic summation of a number of *related pendular* activities; from which it follows as a corollary that an organism, while beating the 22 group, is simultaneously beating its multiples to the amplitudes indicated for each by analysis. Therefore the beater of a 22 group is also beating the 44, 66, 88, etc., in related tempi but in the *same* durations, and the 22 group in *related durations and tempi,* and therefore the condition for the 22 group in any given duration and tempo is also a condition for that same group in related durations and tempi, and for the multiples in related tempi and the same and related durations. What this condition is or was does not presently concern us; we are simply interested in the fact that the organism, when beating the 22 group, is simultaneously beating and simultaneously conditioning multiple groups in related durations and tempi and the same group in related durations and tempi.

The 22 group is complex in still a further way. Very young children do not beat 22 groups or groups as long as the 22. At birth they kick two or three or possibly four times, i. e., they beat the two group, the three group, and the four group, regularly with both upper and lower extremities. On adult observers even we have made similar observations. They regularly start beating rather short groups in the beginning. As their practice periods continue from day to day and from month to month they tend to beat longer and longer groups, and end finally by beating long groups exclusively, with the result that the final records of an observer can hardly be

analyzed without reference to the earlier records. We have cited [7] a rather pretty instance of this in the case of an observer who commenced beating the 22 group (our example is this same 22 group) predominantly; later he beat the first multiple thereof, the 46 group; still later, the third multiple, the 70 group; and finally he was beating the 94 group almost exclusively. To what limits he would have gone it is not difficult to foretell. He was already beating some of the higher multiples, though not predominantly. These facts are of course not new. Of very young children it is said, for instance, that they cannot attend, i. e., perform a certain activity, for any great length of time, but progress in this regard with time and experience. The same is of course true of the adult, except that the latter starts at a little higher level.

Now the important implication of these facts is this, that the 22 group, our stock example of activities in general, is itself but a stage of this developmental process; and just as the 46 group is composed of two 22 groups (we may provisionally think of it in this way), so the 22 group also has similar components. We shall hereafter show that the ancestral form of this component is the 12 group and not the 11 as might be supposed. For certain reasons certain variant forms of the 12 group become stable rather than the 12 group itself, just in the same manner as the 22 group does not develop into the 44 group but generally into the 46 or 47. But the same argument applies to the 12 group. It is also but a stage in the developmental process, and two six groups, or better three four groups, result for its components. Thus we may proceed retrogressively through the several rhythm forms to the ontogenetic limit, and finally end with the beat or simple reflex as the ultimate (with reservations made and yet to be made) activity element. Thus the 22 group, at the same time that it is structurally made up of its multiples, the 44, 66, 88, etc., groups has also the structure indicated by the complex:

$$K = \overline{\overline{\overline{3+1}+\overline{3+1}}+\overline{\overline{2+2+2}+\overline{\overline{2+1}+\overline{2+1}}}}+\overline{\overline{\overline{2+1}+\overline{2+1}}+4+\overline{\overline{2+1}+\overline{2+1}}+4}$$

This does not yet exhaust the simpler structural possibilities of groups. Analysis has shown that the beat may be resolved

[7] *Op. cit.*

into elements each of which can and does occur in variable amplitudes. It must therefore be assumed that the component (the beat) is complex, making for the beat or 'beatlet' property 'amplitude.'

6. Associations and Coordinations.—The general conditions under which associations are formed have been known for some two thousand years or more. They were perhaps first formally enunciated by Aristotle in his now famous laws of association, according to which environmental complexes that act on an organism contiguously in time or space condition therein the corresponding coordinations or associations. It is quite obvious that the Aristotelian formulae explain simultaneous association by the principle of contiguity in space, and successive association by the principle of contiguity in time. During the last few decades the associative law was rediscovered by Pawlow and his students, and enunciated in the physiological form. According to this form of the law, stimuli that act on an organism contiguously in time or space form coordinations therein such that later any one or any number of the contiguously operative elements of the environment finally become adequate for the elicitation of an activity which the whole or any other portion of the environment previously was adequate to elicit.

Our immediate concern is with the conditions which govern the formation of neural coordinations, and with their general nature, particularly in reference to the facts herein presented. For purposes of clearness our discussion must be separated into two parts, namely, one wherein we shall consider only those facts of group activities that are obviously habitual, i. e., which have been formed in postnatal life, and the other wherein we shall consider those facts of group activities that are obviously instinctive, i. e., those that are laid down in the heredity of the organism in question. Among the latter we shall include the coordinations that are implied by the amplitude variations of 'beatlets' as well as those that are implied by the components of a beat. Among the former we shall include the facts of development generally as these have been illustrated by the 22 group in the previous section. We shall consider habitual associations first.

It will be remembered that we have rejected the concatenation idea and its implications in favor of the assumption of a duration mechanism and a rate mechanism in conjunction with each other, and have explained the 22 group in that we assumed the 11.0 second duration mechanism discharging into a rate

mechanism of 0.5 seconds throughout its duration, conditioning thereby 22 cyclic, periodic discharges of the latter. The essential difference between these two conceptions is that the latter assumes a *common condition for a certain definite number of definite activities each of which is thereby conditioned in a definite order in the series which constitutes the whole activity or 'complex,'* the former conditioning each portion of the whole complex of activities by a preceding portion in the sense of the concept of 'reciprocal ennervation,' etc., etc. To the latter concept we shall give the name *'theory of integrands'* whose essence is that there are neural elements, *integrands*, which *integrate* or commonly condition the several activities which constitute a stable association, whether simultaneous or successive, whether homogeneous or heterogeneous, or whether instinctive or habitual, and which are developed from neurones of a younger phylogenetic order; the said development constituting what is commonly termed 'learning.'

For purposes of simplicity we shall proceed on the assumption that a beat is a simple instinctive activity, elicitable, as are reflexes in general, by some adequate environmental stimulus, or 'environmental beat.' In order that two organic beats or reflexes may be elicited, it is necessary that two environmental beats occur and effectively stimulate the organism in question. If now two environmental beats occur as such in a certain definite tempo sufficiently often, each time eliciting two organic beats, a time will presently come when *one* environmental beat suffices or becomes adequate for the elicitation of *two* organic beats. The interval of time between the stage when two environmental beats elicit two organic beats, and when one environmental beat elicits two organic beats, is commonly termed the 'learning' period, and is commonly explained by reference to the electrical concept of 'resistance,' it being said that 'the learning period is consumed in breaking down the resistance of higher paths so-called,' or 'in stamping in paths,' or 'in making synaptical connections of some kind,' etc. Our principal objection to the above kind of conceptions is that they are not biological, or better, that they are teleological. They contain no implications whatsoever which would lead one to believe that the statements made concern living, growing, or developing organisms, and certainly this is a formal requirement which must be basic to any rational conception of the mechanics of learning or developing. Neurones are unicellular animals, no less than amoebae, and the fundamental biological

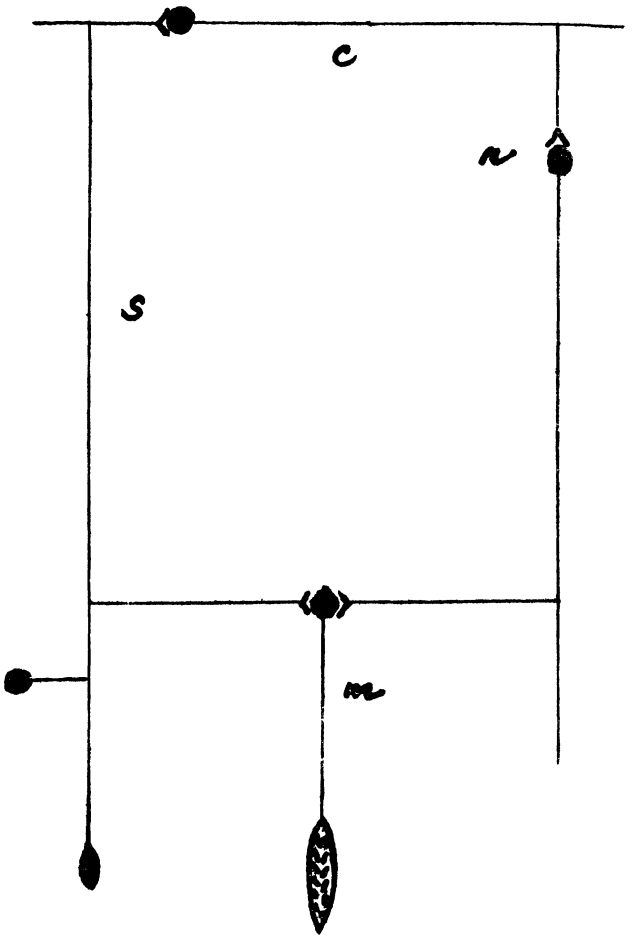


Fig. 9

concepts are as applicable thereto as they are to amoebae or to the unicellulars generally.

Figure 9 is a simple diagram of two superposed reflex arcs which are conceived as having the following properties: the lower arc is simple and is conceived at the level of the cord; the upper arc is also relatively simple, and is conceived partly

cerebral, and partly medullar. The cerebral portion of the upper arc we imagine as having an ultimate discharge period of 1.0 second; the medullar portion as having an instinctive discharge period of 0.5 second. At the time when two environmental beats condition two organic beats we imagine the discharge as taking place through the lower arc; at the time when one environmental beat suffices for the elicitation of two organic beats we imagine the discharge as taking place through both lower and upper arcs. In the interval required for the 'learning,' i. e., for the development of the 'integrand,' we assume a developmental process, conditioned by the discharge of the sensory neurone 's' summatively through the period of learning, as taking place in the cerebral neurone 'c,' of the order of an acceleration of its life activities, or of its metabolism, and a consequent increase of its functional capacity, such that when its phylogenetic limit of development shall have been reached, it will, once stimulated (by 's'), discharge once through an interval or duration of 1.0 second, the said discharge taking place onto or into the rate mechanism 'r' with which it is spatially associated, conditioning therein two periodic cyclic discharges, or ultimately two organic beats, these in the tempo 0.5 second and duration 1.0 second. This is the simple picture of the neural mechanism involved for the beating of simple groups as we conceive it and as we shall hereafter formally develop it in relation to the facts herein presented, as well as in relation to certain other fundamental forms of association, both instinctive and habitual.

Thus conceived, a two-group activity differs from an activity of two beats in several ways. In the first place the two activities are differently conditioned, i. e., they presume different environments. The two group is conditioned by an environment of one beat *provided however that the statistically most frequent environment continues to remain one of two environmental beats, for, unless this remains true, and provided also that the integrand for the two group is itself not conditioned by heredity, it (the integrand) will readapt for the statistically more frequent environment of one beat, and will thereafter not be able to integrate two organic beats.* Structurally the activity in question may be described by the expression,

$$\frac{1}{1 \quad + \quad 1}$$

indicating the unitary character of the group, i. e., recognizing the integrand, and the duality of the activity, i. e., recognizing

the rate mechanism. The expression simultaneously describes the environment by which the group is conditioned, and on account of which it was formed.

There is another way in which the two-group differs from an activity of two beats. The first beat of the two group is obviously conditioned twice, first in the lower arc, then in the upper arc. The second beat is however conditioned but once, and that in the upper arc. In consequence thereof, the amplitudes of the two elements will differ, the amplitude of the first being the greater, and the picture presented will be that of the typical two-rhythm with an accented first beat, i. e., the resultant of beating a one group and a two group simultaneously.

While the formation of the integrand for the two group is proceeding as indicated above, the development of the higher integrands is progressing simultaneously, and to degrees which are proportional to their phylogenetic remoteness from more primitive forms, particularly however, if the environment of one beat or of two beats becomes still more frequent. Through the agencies of the lower integrands these higher integrands will be formed in succession, or developed to the limit of their several phylogenetic capacities, and at intervals during which no apparent developmental progress is being made (plateaus); presently therefore the organism in question will react to one environmental beat by three organic beats, still later by four organic beats, still later by eight organic beats, and finally he will arrive at the stage of the observer who, in the beginning of beating, beat the 22 group predominantly. Thus this process of learning develops progressively with time with the formation of higher and higher integrands, alternating periods of progress (growth) with periods of no apparent progress (plateaus, periods of rest, etc.), until the organism shall have become adapted to the environment in which he casually finds himself, and completing his ontogeny (specific for different organisms) in postnatal life.

It must be remembered that beats are to be conceived as complex events, consisting of an integration of a fundamental plus certain related, i. e., lower partials. It must follow therefore, as a matter of course, than when one beat, say, is being integrated into a two-group, the constituents of a beat (themselves two groups, three groups, four groups, etc.) are conditioning the formation of their own specific integrands. Such integrands will therefore be for certain four, six, eight, etc., beats *in related tempi but in the duration of the original two group integrated simultaneously;* i. e., in the formation of the

two group integrand, the organism will have conditioned integrands for related groups in related tempi but in the duration of that group. And this process proceeds for the higher integrands, i. e., for the formation of the three, four, five group integrands, whose formation will simultaneously condition integrands for the 6, 9, 12, and 15 groups and for the 8, 12, 16, 20 groups, all in the duration of the three and four groups respectively. But the durations of the basic two, three, four, etc., groups are different though related; and as indicated above, the three and four groups will condition each a 12 group integrand among others, but each of these 12 groups will of need have different but related durations. It will become clear, as one imagines this process continuing during the life of the organism, how complex and interrelated the different activities will eventually become, particularly when it is remembered that the integrands for two or more different groups may condition the development of their own specific common condition; i. e., an integrand for a group which can be expressed as the sum of two or more different groups in the record occurring. We have made this observation: that our subjects did not generally beat in related tempi and durations in the beginning, but tended to do so more and more with continued and progressive beating. If this be true, and we incline to the view, one might be tempted to speak in terms of habit formation, but it is to be remarked that the term is applicable only where a specific environmental factor for the habit in question is known to have been operative during the practice period. Such factors we can by no means admit. There is therefore no other way of interpreting the facts of 'relatedness' except on the assumption that beating in related tempi, etc., is instinctive or conditioned prenatally, or at least very early in life.

In the domain of audition where similar facts of relatedness play such a predominant rôle, the same assumptions must, we contend, be made. The average, non-musical lay observer regularly perceives a given tone and its octave synthetically, as Helmholtz puts it, and similarly with the fifth, etc., though progressively less frequently as the order of the partial increases; i. e., relatedness is primary, just as in beating. This means of course that the average lay observer cannot distinguish between an environment which consists of a tone and its octave and one which consists simply of the tone, and this in turn means that he reacts to both environments similarly. An increase in the frequency with which the environment of

one tone occurs now regularly conditions an analytical reaction; that is to say, if the given tone is played alone a number of times, and its octave is also played alone a number of times, the resulting reaction to both simultaneously given is as to each separately but algebraically. In ordinary parlance then, the observer analyzes the clang, but it is to be emphasized that in this case he is simply beating two beats but not a two group, to carry our previous analogy of the two-group over. In psychological terms, in the one case the observer is perceiving a clang, in the other he has simultaneously sensations of the two tones in question. Neurologically therefore it should be quite the same whether one actually beats in related tempi simultaneously or whether one hears related tempi (related tones) simultaneously. We therefore assume the same kind of coordinations for auditory experiences as we have assumed for activities, with the same implications regarding the manner and the conditions under which they have been formed.

The coordinations explained and discussed above assume that there are *elements* to be coordinated and integrated, and the final question arises as to the assumptions which we must make in regard to the elementary neural events by means of which our elementary auditory and beating experiences are conditioned or were conditioned. Our limits of beating extend from about one in two seconds to about ten or twelve in one second. Significantly enough, our lower limits of hearing about coincide with the upper limits of beating, and extend from this point up to about 25,000 per second. We have previously assumed 'rate mechanisms,' and we now complete our assumption with the addendum that the rate mechanisms thus assumed, whether for beating or for hearing, were originally conditioned by both primitive as well as present auditory environments through primitive as well as present sensory mechanisms, the latter being today constituted by the hair-cells of Corti, the only sensory homologues in the cochlea; such sense organs as well as rate mechanisms having periodicities of the same order as the conditioning environments.